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Practitioner's Docket No. 64631-0031

CHAPTER II

TRANSMITTAL LETTER TO THE UNITED STATES ELECTED OFFICE (EO/US)

(ENTRY INTO U.S. NATIONAL PHASE UNDER CHAPTER II)

PCT/US99/04206	25/Feb/1999	25/Feb/1998
INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED

Data Integration and Registration Method and Apparatus for Non-Destructive Evaluation of Materials
TITLE OF INVENTION

Steven M. Shepard
APPLICANT(S)

Box PCT
Assistant Commissioner for Patents
Washington D.C. 20231
ATTENTION: EO/US

NOTE: To avoid abandonment of the application, the applicant shall furnish to the USPTO, not later than 20 months from the priority date: (1) a copy of the international application, unless it has been previously communicated by the International Bureau or unless it was originally filed in the USPTO; and (2) the basic national fee (see 37 C.F.R. § 1.492(a)). The 30-month time limit may not be extended. 37 C.F.R. § 1.495.

WARNING: Where the items are those which can be submitted to complete the entry of the international application into the

CERTIFICATION UNDER 37 C.F.R. 1.10*
*(Express Mail label number is **mandatory**.)*
(Express Mail certification is optional.)

I hereby certify that this correspondence and the documents referred to as attached therein are being deposited with the United States Postal Service on this date 08/25/00, in an envelope as "Express Mail Post Office to Addressee," Mailing Label Number EL686848486US, addressed to the: Assistant Commissioner for Patents, Washington, D.C. 20231.

Joyce Krumpe
(type or print name of person mailing paper)

Joyce Krumpe
Signature of person mailing paper

WARNING: Certificate of mailing (first class) or facsimile transmission procedures of 37 C.F.R. 1.8 cannot be used to obtain a date of mailing or transmission for this correspondence.

WARNING: Each paper or fee filed by "Express Mail" **must have the number of the "Express Mail" mailing label placed thereon prior to mailing. 37 C.F.R. 1.10(b).*
*"Since the filing of correspondence under § 1.10 without the Express Mail mailing label thereon is an oversight that can be avoided by the exercise of reasonable care, requests for waiver of this requirement will **not** be granted on petition." Notice of Oct. 24, 1996, 60 Fed. Reg. 56,439, at 56,442.*

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national phase are subsequent to 30 months from the priority date the application is still considered to be in the international state and if mailing procedures are utilized to obtain a date the express mail procedure of 37 C.F.R. §1.10 must be used (since international application papers are not covered by an ordinary certificate of mailing - See 37 C.F R. §1.8.

NOTE: *Documents and fees must be clearly identified as a submission to enter the national state under 35 USC 371 otherwise the submission will be considered as being made under 35 USC 111. 37 C.F.R. § 1.494(f).*

1. Applicant herewith submits to the United States Elected Office (EO/US) the following items under 35 U.S.C. 371:

   a. [X] This express request to immediately begin national examination procedures (35 U.S.C. 371(f)).

   b. [X] The U.S. National Fee (35 U.S.C. 371(c)(1)) and other fees (37 C.F.R. § 1.492) as indicated below:

2.Fees

CLAIMS FEE	(1) FOR	(2) NUMBER FILED	(3) NUMBER EXTRA	(4) RATE	(5) CALCULATIONS
[ ]*	TOTAL CLAIMS	28 - 20 =	8	x $ 18.00 =	$144.00
	INDEPENDENT CLAIMS	5 - 3 =	2	x $ 78.00 =	156.00
	MULTIPLE DEPENDENT CLAIM(S) (if applicable) + $260.00				
BASIC FEE**	[x] U.S. PTO WAS INTERNATIONAL PRELIMINARY EXAMINATION AUTHORITY Where an International preliminary examination fee as set forth in § 1.482 has been paid on the international application to the U.S. PTO: [ ] and the international preliminary examination report states that the criteria of novelty, inventive step (non-obviousness) and industrial activity, as defined in PCT Article 33(2) to (4) have been satisfied for all the claims presented in the application entering the national stage (37 CFR 1.492(a)(4)) ..... $96.00 [x] and the above requirements are not met (37 CFR 1.492(a)(1)) ..... $670.00 [ ] U.S. PTO WAS NOT INTERNATIONAL PRELIMINARY EXAMINATION AUTHORITY Where no international preliminary examination fee as set forth in § 1.482 has been paid to the U.S. PTO, and payment of an international search fee as set forth in § 1.445(a)(2) to the U.S. PTO: [ ] has been paid (37 CFR 1.492(a)(2)) ..... $760.00 [ ] has not been paid (37 CFR 1.492(a)(3)) ..... $970.00 [ ] where a search report on the international application has been prepared by the European Patent Office or the Japanese Patent Office (37 CFR 1.492(a)(5)) $840.00				$670.00
	Total of above Calculations				= 970.00
SMALL ENTITY	Reduction by ½ for filing by small entity, if applicable. Affidavit must be filed. (note 37 CFR 1.9, 1.27, 1.28)				-$485.00
	Subtotal				$485.00
	Total National Fee				$ 485.00
	Fee for recording the enclosed assignment document $40.00 (37 CFR 1.21(h)). (See Item 13 below). See attached "ASSIGNMENT COVER SHEET".				
TOTAL	Total Fees enclosed				$ 485.00

*See attached Preliminary Amendment Reducing the Number of Claims.

i. [ ] A check in the amount of _____ to cover the above fees is enclosed.

ii. [X] Please charge Account No. 18-0013 in the amount of $ 485.00. A duplicate copy of this sheet is enclosed.

**WARNING: *"To avoid abandonment of the application the applicant shall furnish to the United States Patent and Trademark Office not later than the expiration of 30 months from the priority date: * * * (2) the basic national fee (see § 1.492(a)). The 30-month time limit may not be extended." 37 C.F.R. § 1.495(b).*

WARNING: *If the translation of the international application and/or the oath or declaration have not been submitted by the applicant within thirty (30) months from the priority date, such requirements may be met within a time period set by the Office. 37 C.F.R. § 1.495(b)(2). The payment of the surcharge set forth in § 1.492(e) is required as a condition for accepting the oath or declaration later than thirty (30) months after the priority date. The payment of the processing fee set forth in § 1.492(f) is required for acceptance of an English translation later than thirty (30) months after the priority date. Failure to comply with these requirements will result in abandonment of the application. The provisions of § 1.136 apply to the period which is set. Notice of Jan. 3, 1993, 1147 O.G. 29 to 40.*

3. [X] A copy of the International application as filed (35 U.S.C. 371(c)(2)):

NOTE: *Section 1.495 (b) was amended to require that the basic national fee and a copy of the international application must be filed with the Office by 30 months from the priority date to avoid abandonment "The International Bureau normally provides the copy of the international application to the Office in accordance with PCT Article 20. At the same time, the International Bureau notifies applicant of the communication to the Office. In accordance with PCT Rule 47.1, that notice shall be accepted by all designated offices as conclusive evidence that the communication has duly taken place. Thus, if the applicant desires to enter the national stage, the applicant normally need only check to be sure the notice from the International Bureau has been received and then pay the basic national fee by 30 months from the priority date." Notice of Jan. 7, 1993, 1147 O.G. 29 to 40, at 35-36. See item 14c below.*

a. [X] is transmitted herewith.

b. [ ] is not required, as the application was filed with the United States Receiving Office.

c. [ ] has been transmitted

i. [ ] by the International Bureau.
Date of mailing of the application (from form PCT/IB/308): _____.

ii. [ ] by applicant on _____.
Date

4. [X] A translation of the International application into the English language (35 U.S.C. 371(c)(2)):

a. [ ] is transmitted herewith.

b. [x] is not required as the application was filed in English.

c. [ ] was previously transmitted by applicant on _____.
Date

d. [ ] will follow.

5. [ ] Amendments to the claims of the International application under PCT Article 19 (35 U.S.C. 371(c)(3)):

NOTE: The Notice of January 7, 1993 points out that 37 C.F.R. § 1.495(a) was amended to clarify the existing and continuing practice that PCT Article 19 amendments must be submitted by 30 months from the priority date and this deadline may not be extended. The Notice further advises that: "The failure to do so will not result in loss of the subject matter of the PCT Article 19 amendments. Applicant may submit that subject matter in a preliminary amendment filed under section 1.121. In many cases, filing an amendment under section 1.121 is preferable since grammatical or idiomatic errors may be corrected." 1147 O.G. 29-40, at 36.

a. [ ] are transmitted herewith.
b. [ ] have been transmitted
   i. [ ] by the International Bureau.
   Date of mailing of the amendment (from form PCT/IB/308): _____.
   ii. [ ] by applicant on _____.
   Date
c. [ ] have not been transmitted as
   i. [ ] applicant chose not to make amendments under PCT Article 19.
   Date of mailing of Search Report (from form PCT/ISA/210): _____.
   ii. [ ] the time limit for the submission of amendments has not yet expired. The amendments or a statement that amendments have not been made will be transmitted before the expiration of the time limit under PCT Rule 46.1.

6. [ ] A translation of the amendments to the claims under PCT Article 19 (38 U.S.C. 371(c)(3)):
   a. [ ] is transmitted herewith.
   b. [ ] is not required as the amendments were made in the English language.
   c. [ ] has not been transmitted for reasons indicated at point 5(c) above.

7. [x] A copy of the international examination report (PCT/IPEA/409)
   [x] is transmitted herewith.
   [ ] is not required as the application was filed with the United States Receiving Office.

8. [x] Annex(es) to the international preliminary examination report
   a. [ ] is/are transmitted herewith.
   b. [x] is/are not required as the application was filed with the United States Receiving Office.

9. [ ] A translation of the annexes to the international preliminary examination report
   a. [ ] is transmitted herewith.
   b. [ ] is not required as the annexes are in the English language.

10. [X] An oath or declaration of the inventor (35 U.S.C. 371(c)(4)) complying with 35 U.S.C. 115
   a. [ ] was previously submitted by applicant on _____.
   Date
   b. [ ] is submitted herewith, and such oath or declaration
      i. [ ] is attached to the application.
      ii. [ ] identifies the application and any amendments under PCT Article 19 that were transmitted as stated in points 3(b) or 3(c) and 5(b); and states that they were reviewed by the inventor as required by 37 C.F.R. 1.70.

iii. [X] will follow.

Other document(s) or information included:

11. [x] An International Search Report (PCT/ISA/210) or Declaration under PCT Article 17(2)(a):
    a. [ ] is transmitted herewith.
    b. [ ] has been transmitted by the International Bureau.
       Date of mailing (from form PCT/IB/308): _____.
    c. [x] is not required, as the application was searched by the United States International Searching Authority.
    d. [ ] will be transmitted promptly upon request.
    e. [ ] has been submitted by applicant on _____.
       Date

12. [X] An Information Disclosure Statement under 37 C.F.R. 1.97 and 1.98:
    a. [ ] is transmitted herewith.
       Also transmitted herewith is/are:
       [ ] Form PTO-1449 (PTO/SB/08A and 08B).
       [ ] Copies of citations listed.
    b. [x] will be transmitted within THREE MONTHS of the date of submission of requirements under 35 U.S.C. 371(c).
    c. [ ] was previously submitted by applicant on _____.
       Date

13. [ ] An assignment document is transmitted herewith for recording.

A separate [ ] "COVER SHEET FOR ASSIGNMENT (DOCUMENT) ACCOMPANYING NEW PATENT APPLICATION" or[ ] FORM PTO 1595 is also attached.

_____
_____
_____

14. [X] Additional documents:
    a. [ ] Copy of request (PCT/RO/101)
    b. [x] International Publication No. WO99/44366
       i. [ ] Specification, claims and drawing
       ii. [x] Front page only
    c. [ ] Preliminary amendment (37 C.F.R. § 1.121)
    d. [ ] Other

_____
_____
_____

15. [X] The above checked items are being transmitted

a. [X] before 30 months from any claimed priority date.
b. [ ] after 30 months.

16. [ ] Certain requirements under 35 U.S.C. 371 were previously submitted by the applicant on _____, namely:

_____
_____
_____

AUTHORIZATION TO CHARGE ADDITIONAL FEES

WARNING: *Accurately count claims, especially multiple dependent claims, to avoid unexpected high charges if extra claims are authorized.*

NOTE: *"A written request may be submitted in an application that is an authorization to treat any concurrent or future reply, requiring a petition for an extension of time under this paragraph for its timely submission, as incorporating a petition for extension of time for the appropriate length of time. An authorization to charge all required fees, fees under § 1.17, or all required extension of time fees will be treated as a constructive petition for an extension of time in any concurrent or future reply requiring a petition for an extension of time under this paragraph for its timely submission. Submission of the fee set forth in § 1.17(a) will also be treated as a constructive petition for an extension of time in any concurrent reply requiring a petition for an extension of time under this paragraph for its timely submission." 37 C.F.R. § 1.136(a)(3).*

NOTE: *"Amounts of twenty-five dollars or less will not be returned unless specifically requested within a reasonable time, nor will the payer be notified of such amounts; amounts over twenty-five dollars may be returned by check or, if requested, by credit to a deposit account." 37 C.F.R. § 1.26(a).*

[X] The Commissioner is hereby authorized to charge the following additional fees that may be required by this paper and during the entire pendency of this application to Account No. 18-0013.

[X] 37 C.F.R. 1.492(a)(1), (2), (3), and (4) (filing fees)

WARNING: *Because failure to pay the national fee within 30 months without extension (37 C.F.R. § 1.495(b)(2)) results in abandonment of the application, it would be best to always check the above box.*

[X] 37 C.F.R. 1.492(b), (c) and (d) (presentation of extra claims)

NOTE: *Because additional fees for excess or multiple dependent claims not paid on filing or on later presentation must only be paid or these claims cancelled by amendment prior to the expiration of the time period set for response by the PTO in any notice of fee deficiency (37 C.F.R. § 1.492(d)), it might be best not to authorize the PTO to charge additional claim fees, except possible when dealing with amendments after final action.*

[X] 37 C.F.R. 1.17 (application processing fees)
[X] 37 C.F.R. 1.17(a)(1)-(5)(extension fees pursuant to § 1.136(a).
[ ] 37 C.F.R. 1.18 (issue fee at or before mailing of Notice of Allowance, pursuant to 37 C.F.R. 1.311(b))

NOTE: *Where an authorization to charge the issue fee to a deposit account has been filed before the mailing of a Notice of Allowance, the issue fee will be automatically charged to the deposit account at the time of mailing the notice of*

allowance. 37 C.F.R. § 1.311(b).

NOTE: 37 C.F.R. 1.28(b) requires "Notification of any change in loss of entitlement to small entity status must be filed in the application . . . prior to paying, or at the time of paying . . . issue fee." From the wording of 37 C.F.R. § 1.28(b): (a) notification of change of status must be made even if the fee is paid as "other than a small entity" and (b) no notification is required if the change is to another small entity.

[X] 37 C.F.R. § 1.492(e) and (f) (surcharge fees for filing the declaration and/or filing an English translation of an International Application later than 30 months after the priority date).

SIGNATURE OF PRACTITIONER

Reg. No.: 33,373

Joseph V. Coppola, Sr.
(type or print name of practitioner)

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DATA INTEGRATION AND REGISTRATION METHOD AND APPARATUS FOR NON-DESTRUCTIVE EVALUATION OF MATERIALS

TECHNICAL FIELD

The present invention is directed to a method and apparatus for non-destructive testing and evaluation of materials, and more particularly to a method and apparatus for identifying and registering defects in a sample by superimposing a defect image over a live image to locate subsurface defects in the sample.

BACKGROUND ART

Various methods of non-destructive testing and evaluation (NDT/E) of parts have been developed to detect subsurface defects in a part sample and to measure the depth of subsurface defects. These methods include step thermography, pulse thermography, pulse thermography, and other thermographic techniques. All of these techniques involve deliberately changing the temperature of the sample, allowing the sample to return to equilibrium temperature, and observing the temperature change of the sample via an infrared camera. Anomalous temperature changes that appear in the infrared camera image indicate subsurface defects in the sample; subsurface defects tend to impede the normal heat flow in the sample and will appear as anomalies in the image. Further, because the infrared image showing the defect is transient and may last for only a fraction of a second, the image must be captured (usually with a digital computer) and then verified with the actual sample to locate the defect.

The actual verification process, usually through a complementary NDT/E process, can be relatively difficult because the infrared defect image of the sample may bear little resemblance to the actual sample. For example, many subsurface defects appear only in the infrared image; to the naked eye, the sample containing the defects often appears perfectly uniform. As a result, a user must attempt to match the image of the subsurface defect with the actual, unblemished sample surface to pinpoint the location of the defect. This is further complicated by the fact that the infrared camera lens often distorts the image, causing straight lines at the periphery of the lens's field of view to appear curved in the image. To locate and mark the positions of subsurface

defects with some precision, prior art methods include using regularly spaced registration markers on the sample, calculating complex anamorphic mapping algorithms, or printing a full-size defect image and physically matching or overlaying the full-size image onto the actual sample. Because the sample may not have any distinguishing marks that appear in the defect image, precise registration of the image and the sample's surface can be difficult. In addition, these methods are time-consuming and are not particularly convenient, and at best they can only approximate the subsurface defect location due to the image distortion from the infrared camera lens. Further, measuring the depth of subsurface defects often requires some prior knowledge of the sample's dimensions or properties, such as the thickness of the sample, the depth of a known defect, the material's thermal diffusivity, etc. This information is often not available in practice, making precise depth measurements difficult with known techniques.

Thus, there currently is a need for a NDT/E technique that allows accurate annotation, marking, and thickness measurements of specific locations on a sample, without the problems caused by differences between the image and the actual sample due to image distortion. There is also a need for a NDT/E technique that can conduct depth measurement without requiring prior knowledge of any of the sample's characteristics. If the depth and onset time (relative to the heating event) of a single defect are known, it is then possible to calculate the thermal diffusivity of the material and to use it to determine the depths of other defects from their offset time, according to the well-known relation of $t = d^2 / D$, where t is the onset time, d is the depth of the defect, and D is the thermal diffusivity of the sample.

SUMMARY OF THE INVENTION

Accordingly, the present invention is a method and apparatus for conducting NDT/E that simplifies the correspondence between image information obtained during NDT/E and the actual sample. More specifically, the invention involves obtaining a defect image and a live image of the same sample and then superimposing one image on the other. One embodiment of the invention is directed to linking the information regarding surface defects obtained during infrared NDT/E to the actual part being inspected. The invention includes generating a defect image of the sample via infrared

imaging or some other means. The defect image may have markers or other indicia locating where subsurface defects are in the sample. The defect image is then superimposed onto a live image of the sample. A user then views the live image of the sample, rather than the sample itself, while transferring the marks from the defect image to the sample. Because both the defect image and the live image are distorted by the infrared camera lens and therefore have a one-to-one correspondence, the distorted image is used as the frame of reference for locating subsurface defects and marking the sample. This ensures that the marks in the defect image are transferred precisely from the defect image onto the sample and also eliminates the need to map the distorted image to the sample in a separate step.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a flowchart illustrating an evaluation and testing method according to the present invention;

Figure 2 is a flowchart illustrating an example of the inventive method as applied to thermography;

Figures 3a through 3f illustrate actual images taken from infrared NDT/E of an aluminum aircraft panel according to the method of the present invention; and

Figure 4 is a representative diagram of an apparatus that can be used to annotate, calibrate, and/or evaluate a sample according to the method of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to Figure 1, one embodiment of the NDT/E method according to the present invention can be broken down into four steps. First, a defect image of the sample is obtained 100, digitized and displayed on a computer 102 using a computer program that has a referencing mechanism, such as drawing tool that allows the user to draw on the defect image using a mouse, touch screen, light pen, or other pointing device. The user can mark defects found in the defect image with the drawing tool 103. The defect image, including any marks made by the user, is then superimposed onto a live image 104, which is also displayed on the computer. The live image is preferably produced immediately thereafter and using the same lens and camera that produced the defect

image to ensure a one-to-one correspondence between the live image and the defect image; using the same lens ensures that both images will have the same distortion. The user then marks the actual sample, using a marking pencil or similar device, while viewing the live image 106 rather than looking the sample itself. Instead of marking the part, the user may also use a point measuring device to measure characteristics of the sample, such as its thickness, and append the data to the image for annotation or calibration purposes. The defect image and live image can also be simply superimposed one atop the other for referencing purposes, without any user intervention.

As noted above, the defect image is subject to any lens distortion that may be present. In the prior art, inaccuracies in marking occurred because the user was attempting to map the distorted defect image onto a corresponding physical sample part, whether it was through markers on the sample or through overlaying a full-size image on the actual sample. In the invention, however, the user watches the live image of the sample rather than the sample itself when referencing the sample. Because the live image and the defect image in the present invention are both distorted via the same camera lens, the defect image and the live image align perfectly with each other. Further, the user will look at the live image of the marking or measurement instrument, and not the actual marking/measurement instrument itself, in real time while referencing the sample, making it possible to trace the marks from the defect image onto the sample precisely and distortion-free. In short, the distorted defect image and the distorted live image both have exactly the same, albeit distorted, frame of reference. Thus, any marks or measurements taken while viewing the live image will correspond exactly to the marked locations in the defect image superimposed on the live image.

Referring now to Figures 2 and 3a through 3f, the method of the present invention will now be described with respect to thermography. Note that the invention is not limited to such an application and can be used in any application where accurate mapping between an image of a sample and the sample itself is needed. The first step involves changing the sample's temperature 200 by heating or cooling the temperature through any known method. For example, heat can be applied to the sample via a flashlamp or a continuous lighting source. Defect images of the sample are then taken 202 with an infrared camera as the sample's temperature returns to equilibrium. The

infrared camera preferably obtains multiple defect images from the same sample after the sample's temperature is changed, taking images at selected time intervals as the sample returns to equilibrium temperature. Figures 3a through 3d illustrate a time sequence of infrared images of an aluminum aircraft pane adhesively bonded to an aluminum structural frame, illustrating the transient nature of infrared NDT/E. Figure 3a was taken just before heating, Figure 3b taken 1.33 seconds after heating, Figure 3c taken 10.67 seconds after heating, and Figure 3d taken 39.34 seconds after heating. As can be seen in the figures, the aircraft panel does not exhibit any subsurface structure before heating (Figure 3a), while just after heating, the frame can be seen in the defect image, along with a disbonded area where corrosion has occurred, in the right half of the image (Figure 3b). The frame and disbonded area are less distinct after 10.67 seconds (Figure 3c) and disappear completely after 39.34 seconds (Figure 3d). For non-destructive evaluation, the image obtained shown in Figure 3b provides the most useful information because it is the clearest image.

Once the desired defect image is selected, it is digitized and transferred to the computer 204 for display on a computer monitor. The defect image is preferably displayed using a program with a "draw" mode so that the user can place marks on the defect image using a mouse, touch screen, or other pointing device. The area where the defects occur is then "marked" on the screen by the user 206. An example of such a display is shown in Figure 3e, where the image from Figure 3b is taken as the defect image. As can be seen in Figure 3e, the area where the plate defect appears has been circled by the user, using the "draw" mode in the computer program generating the defect image, to highlight the area at which the subsurface defect is located.

Once the defect image is marked 206, it is superimposed onto a digitized live image 208, which is also displayed on the computer monitor. As explained above, because both the defect image and the live image are obtained using the same infrared camera lens and because the camera is not moved after the defect image is obtained, both the defect image and the live image exhibit the same amount of lens distortion and have a one-to-one correspondence with each other; the defect image and live image do not have any distortion with respect to each other. Once the defect image is superimposed on the live image, the user can transfer the reference marks from the defect image to the

sample 210 exactly and distortion-free. As shown in Figure 3f, the user does this by viewing his hand (or the marking instrument) on the sample via the live image, not by directly watching the physical sample. Because of the one-to-one correspondence between the defect image and the live image, and because the user views the live image while referencing the actual sample, the marks are made on the actual sample precisely correspond to the location of the defect. Alternatively, or in addition to the marking, the user may also contact the sample with a point measuring probe, such as an ultrasonic thickness gauge or thermocouple, to measure the local properties of the sample. Because the probe will appear in the live image, the user can mark the position of the probe on the defect image and then read the probe measurement through a serial data connection. The information can be appended to the image for annotation or calibration purposes.

Many different apparatus configurations can be used to carry out the method of the present invention. For example, although the above method has been described using a digital computer for receiving image data from the infrared camera, many infrared cameras have onboard displays and dedicated microcontrollers. Thus, most if not all of the steps explained above can be integrated into the camera itself. The user can perform the outlining/marking operation using cursor keys already resident on the camera. Further, the marking/annotation steps can be conducted using image processing/machine vision methods rather than manually by the user. Also, all of the above steps can be completely automated if, for example, a 3-D map of the sample is stored in the computer. In such a case, the computer itself could conduct the superimposing, referencing, and correlating based on the information in the 3-D map, without user intervention.

Figure 4 illustrates one apparatus that can be used to carry out the inventive method with respect to thermography. The apparatus includes a reflective hood 400 that focuses light from heating lamps 402 onto a sample 404. The heating lamps 402 can be flashlamps (e.g. xenon lamps) or continuous lamps (e.g. halogen lamps). Regardless of the type of lamp used, reflectors 403 or some other means should be used to distribute light uniformly over the sample 404 surface at the opinion of the hood 400 so that the sample heats evenly. The front end of the hood 400 is open and is placed on or near the sample 404. The back portion of the hood 400 is designed to accommodate a lens 406 of

an infrared camera 408. The hood 400 also preferably has an access door 410 to allow the user to reach inside the hood 400 and mark the sample, if desired.

The apparatus shown in Figure 4 also includes a display 412 for displaying the defect image and the live image generated by the infrared camera 408. The apparatus also includes a microcontroller or personal computer 414, which may be located in the infrared camera 408 itself, attached to the thermography apparatus in some other way, or located remotely and accessed via 2-way serial or parallel data communication. A measuring instrument 416, such as an ultrasonic thickness gauge, can also be provided to conduct thickness measurements or other measurements. Lastly, a user interface 418, such as an operator keypad or touch screen, is provided on the apparatus to allow marking of the defect image and manipulation of the images on the display 412.

In summary, because the invention uses a distorted live image and a distorted defect image to locate subsurface defects, the one-to-one correspondence between the two distorted images creates a new frame of reference from which to pinpoint the defect locations, greatly increasing the accuracy and speed at which subsurface defects can be located and marked. The invention also allows complementary NDT/E methods to be used in conjunction with the defect image so that the defect image can be annotated or can be calibrated so thickness measurements can be obtained directly from the image, without requiring prior information from a reference sample or any other source. Further, the invention can be used with any infrared NDT/E method, independently of how the method changes the sample's temperature, generates the defect image, or processes the data.

It should be understood that various alternatives to the embodiments of the invention described herein may be employed in practicing the invention. It is intended that the following claims define the scope of the invention and that the method and apparatus within the scope of these claims and their equivalents be covered thereby.

CLAIMS

I CLAIM:

1. A method for non-destructive evaluation of a sample, comprising the steps of:

obtaining a defect image and a live image of the sample, the defect image and the live image having a one-to-one correspondence with each other; and

superimposing one of the defect image and the live image on the other of the defect image and the live image.

2. The method of claim 1, further comprising the steps of:

locating a defect in the sample via the defect image;

referencing the defect image according to the located defect; and

referencing the sample based on the referenced defect image while viewing the live image and the referenced defect image on a display.

3. The method of claim 2, wherein the step of referencing the defect image includes the step of marking the sample according to the referenced defect image.

4. The method of claim 2, wherein the step of referencing the defect image includes the step of measuring a characteristic of the sample at a selected location.

5. A method for non-destructive evaluation of a sample, comprising the steps of:

obtaining a defect image and a live image of the sample, the defect image and the live image having a one-to-one correspondence with each other;

displaying the defect image on a digital display;

superimposing the defect image onto the live image on the display; and

referencing the sample while viewing the live image and the defect image on the display.

6. The method of claim 5, wherein the defect image is an infrared image, and wherein the defect image and the live image are obtained from an infrared camera.

7. The method of claim 6, further comprising the steps of:

changing the temperature of the sample; and

obtaining at least one defect image over time to locate a defect in the sample.

8. The method of claim 7, wherein the changing step includes directing a heating pulse onto the sample such that the heat is distributed evenly over the sample.

9. The method of claim 7, wherein the changing step includes directing continuous heat onto the sample such that the heat is distributed evenly over the sample.

10. The method of claim 5, wherein the referencing step includes the steps of:

measuring a characteristic of the sample at a selected location; and

annotating the defect image with data obtained from the measuring step.

11. The method of claim 6, wherein the referencing step includes the steps of:

measuring a characteristic of the sample at a selected location; and

annotating the defect image with data obtained from the measuring step.

12. The method of claim 5, wherein the obtaining, displaying, superimposing and referencing steps are automated and conducted in a computer.

13. An apparatus for non-destructive testing/evaluation of a sample, comprising:

a camera that generates a defect image and a live image of the sample;

a processor coupled with the camera to digitize the defect image and the live image;

a display for displaying the digitized defect image and the live image, wherein the processor and the display include means for referencing the defect image and

superimposing one of the defect image and the live image onto the other of the defect image and the live image.

14. The apparatus of claim 13, wherein the processor and the display are constructed as part of the camera.

15. The apparatus of claim 13, wherein the camera is an infrared camera, and wherein the apparatus further comprises:

a hood having a reflective interior and an opening for the camera at a back portion and an open end at the front portion, wherein the sample is disposed in the front portion of the hood; and

at least one heating lamp disposed inside the hood to heat the sample.

16. The apparatus of claim 15, wherein the hood has a door to allow physical access to the sample by the user.

17. A computer readable storage device used to control non-destructive testing and evaluation of materials, comprising the steps of:

obtaining a defect image and a live image of the sample, the defect image and the live image having a one-to-one correspondence with each other; and

superimposing one of the defect image and the live image on the other of the defect image and the live image.

18. The computer readable storage device of claim 17, further comprising the steps of:

locating a defect in the sample via the defect image;

referencing the defect image according to the located defects; and

referencing the sample after the superimposing step while viewing the live image and the referenced defect image on a display.

19. The computer readable storage device of claim 18, wherein the step of referencing the defect image includes the step of marking the sample according to the referenced defect image.

20. The computer readable storage device of claim 18, wherein the step of referencing the defect image includes the step of measuring a characteristic of the sample at a selected location.

21. A computer readable storage device for non-destructive evaluation of a sample, comprising the steps of:

obtaining a defect image and a live image of the sample, the defect image and the live image having a one-to-one correspondence with each other;

displaying the defect image on a digital display;

superimposing the defect image onto the live image on the display; and

referencing the sample while viewing the live image and the defect image on the display.

22. The computer readable storage device of claim 21, wherein the defect image is an infrared image, and wherein the defect image and the live image are obtained from an infrared camera.

23. The computer readable storage device of claim 22, further comprising the steps of:

changing the temperature of the sample; and

obtaining at least one defect image over time to locate a defect in the sample.

24. The computer readable storage device of claim 23, wherein the changing step includes directing a heating pulse onto the sample such that the heat is distributed evenly over the sample.

25. The computer readable storage device of claim 23, wherein the changing step includes directing continuous heat onto the sample such that the heat is distributed evenly over the sample.

26. The computer readable storage device of claim 21, wherein the referencing step includes the steps of:

measuring a characteristic of the sample at a selected location; and

annotating the defect image with data obtained from the measuring step.

27. The computer readable storage device of claim 22, wherein the referencing step includes the steps of:

measuring a characteristic of the sample at a selected location; and

annotating the defect image with data obtained from the measuring step.

28. The computer readable storage device of claim 21, wherein the obtaining, displaying, superimposing and referencing steps are automated and conducted in a computer.

ABSTRACT OF THE DISCLOSURE

A method an apparatus for non-destructive testing and evaluation of part samples includes obtaining a defect image of the sample, displaying the defect image on a display, referencing the defect image, such as through marking or annotation, to highlight locations at which defects or measurements are found, superimposing the defect image onto a live image of the part, and physically marking/annotating the part, tracing the marks from the defect image onto the physical sample, while viewing the live image. Because both the defect image and the live image are viewed through the same camera lens and are therefore subject to the same amount of distortion, the actual sample can be marked exactly according to the marks made in the defect image; there is no need to attempt matching a distorted defect image with the physical sample, as has been done in the prior art. This one-to-one correspondence between the defect image and the live display enables precise marking of the physical sample since the user looks at the distorted live image of the sample, not the physical sample itself, during the marking process. The method is particularly useful for detecting subsurface defects in a sample via thermographic techniques.

R0048519

64631-012

VERIFIED STATEMENT BY INVENTOR CLAIMING SMALL ENTITY STATUS (37 C.F.R. 1.9(f) and 1.27(c))

As a below named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 CFR 1.9(c) for purposes of paying reduced fees under Section 41(a) and (b) of Title 35, United States Code, to the Patent and Trademark Office with regard to the invention entitled:

DATA INTEGRATION AND MARKING FOR INFRARED NONDESTRUCTIVE EVALUATION

described in the specification filed on February 25, 1998, Serial No. 60/075,920.

I have not assigned, granted, conveyed or licensed and am under no obligation under contract or law to assign, grant, convey or license, any rights in the invention to any person who could not be classified as an independent inventor under 37 CFR 1.9(c) if that person had made the invention, or to any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

None

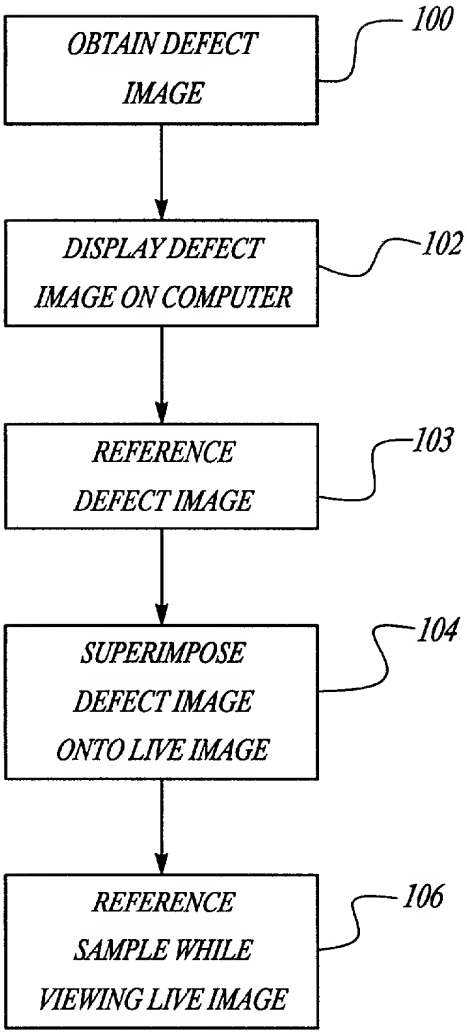
I acknowledge the duty to file, in this application or patent, notification of any change in status result in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b)).

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent to which this verified statement is directed.

Dated: April 29, 1998
SNS

Steven M. Shepard
23656 Hunter's Lane
Southfield MI 48034

R0022811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100
DISPLAY DEFECT IMAGE ON COMPUTER
102
REFERENCE DEFECT IMAGE
103
SUPERIMPOSE DEFECT IMAGE ONTO LIVE IMAGE
104
REFERENCE SAMPLE WHILE VIEWING LIVE IMAGE
106

Fig-1

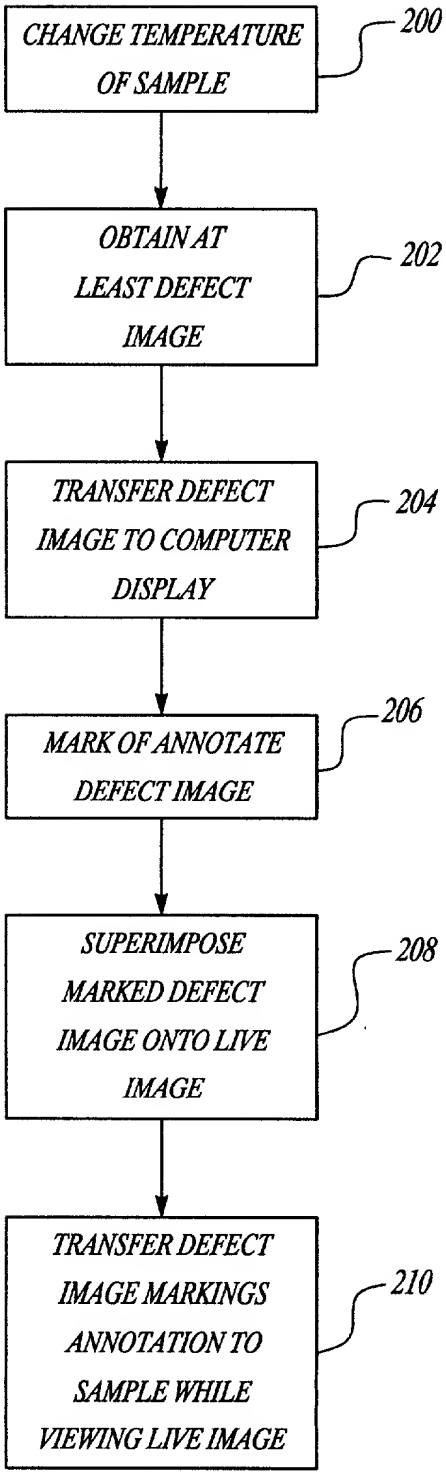
CHANGE TEMPERATURE OF SAMPLE
200
OBTAIN AT LEAST DEFECT IMAGE
202
TRANSFER DEFECT IMAGE TO COMPUTER DISPLAY
204
MARK OF ANNOTATE DEFECT IMAGE
206
SUPERIMPOSE MARKED DEFECT IMAGE ONTO LIVE IMAGE
208
TRANSFER DEFECT IMAGE MARKINGS ANNOTATION TO SAMPLE WHILE VIEWING LIVE IMAGE
210

Fig-2

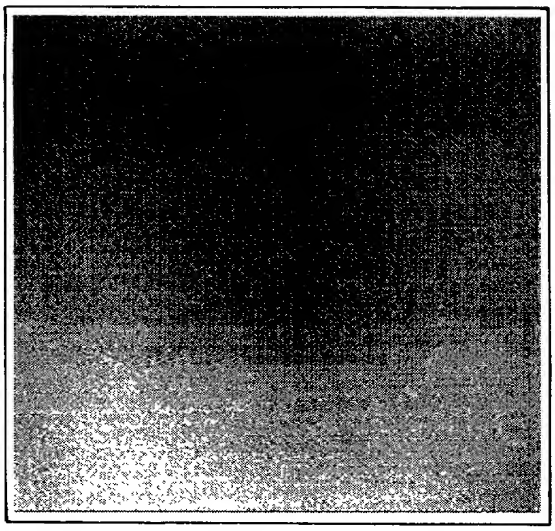

Fig-3A

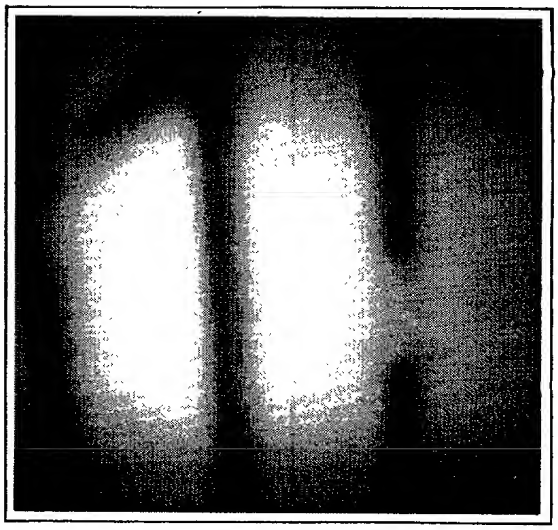

Fig-3B

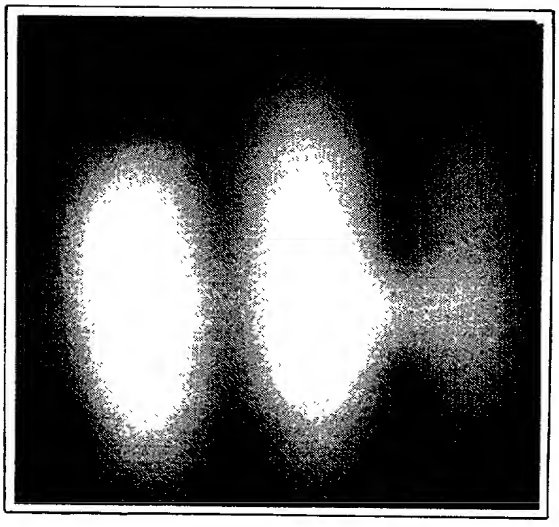

Fig-3C

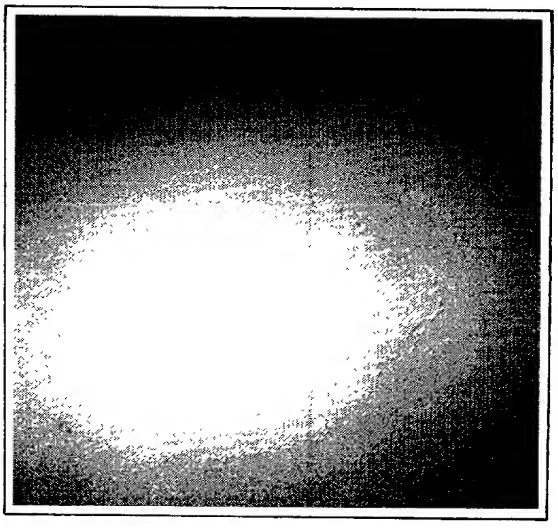

Fig-3D

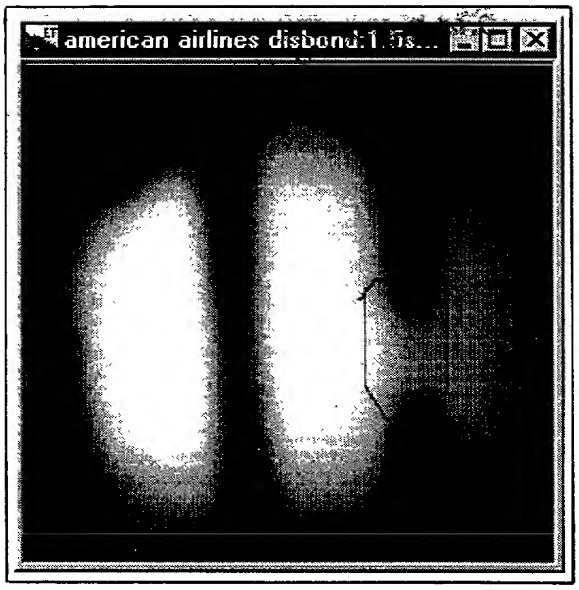

Fig-3E

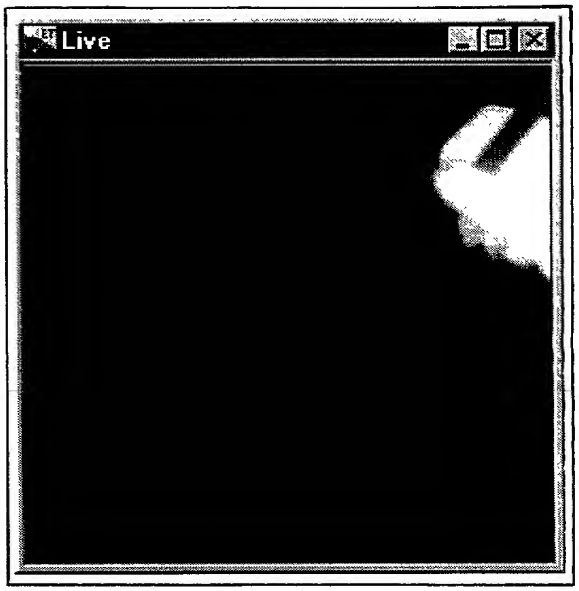

Fig-3F

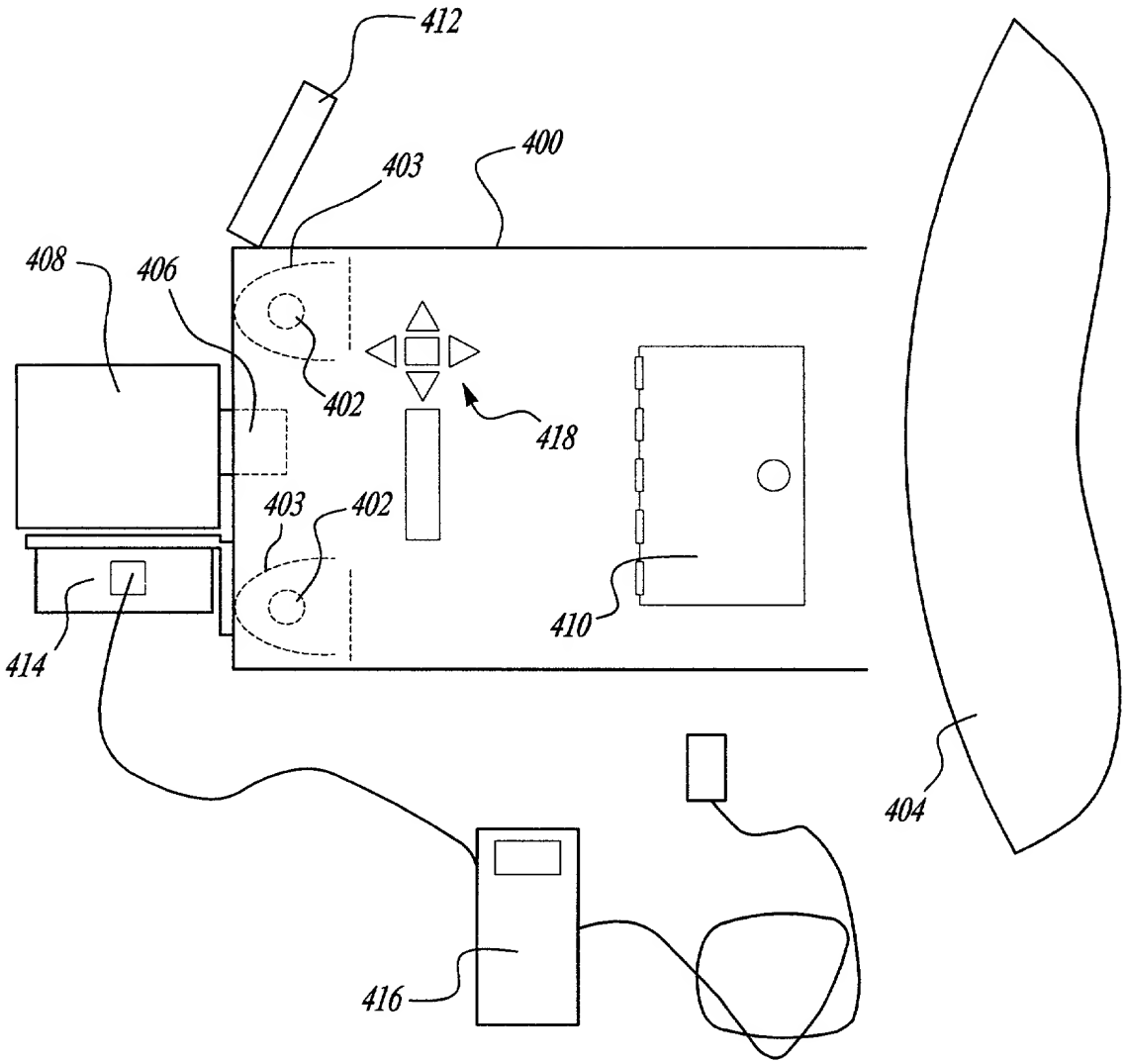

Fig-4

Please type a plus sign in this box: [+]

PTO/SB/01 (3-97)
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DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION

☐ Declaration Submitted with or initial filing

☒ Declaration Submitted after initial filing

Attorney Docket No.	64631-031
First Named Inventor	Steve M. Shepard
COMPLETE IF KNOWN	
Application No.	09/623071
Filing Date	08/25/00
Group Art Unit	
Examiner Name	

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (only if one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

Data Integration and Registration Method and Apparatus for Non-Destructive Evaluation of Materials

(Title of the Invention)

the specification of which

☐ is attached hereto
or

☒ was filed on February 25, 1999, as United States Application Number or PCT International Application Number: PCT/US99/04206 and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations § 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code §119 (a)-(d) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YY)	Priority Not Claimed	Certified Copy Attached YES	NO
				☐	☐
				☐	☐
				☐	☐

☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto

I hereby claim the benefit under Title 35, United States Code §119(e) of any United States provisional application(s) listed below.

Application Number (s)	Filing Date (MM/DD/YY)
60/075,920	02/25/98

☐ Additional provisional application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

Please type a plus sign in this box: [+]

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DECLARATION - Utility Or Design Patent Application

I hereby claim the benefit under Title 35, United States Code §120 of any United States application(s) of any PCT International application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the matter provided by the first paragraph of Title 35, United States Code §112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S Parent Application Number	PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number (If applicable)

☐ Additional U.S or PCT International application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto

As a named inventor, I hereby appoint the following registered practitioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

☒ Customer Number 010291

Or

☐ Registered practitioner(s) name/registration number listed below

Place Customer Number Bar Code Label Here

Name	Registration Number	Name	Registration Number
JOSEPH V. COPPOLA, SR.	33373		

☐ Additional registered practitioner(s) named on supplemental Registered Practitioner Information sheet PTO/SB/02C attached hereto.

Direct all correspondence to ☒ Customer Number or Bar Code Label 010291 or ☐ Correspondence Address below

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Country	US	Telephone	248-594-0650	Fax	248-594-0610

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name of Sole or First Inventor ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])	Family Name or Surname
STEVEN M.	SHEPARD

Inventor's Signature	Steven M. Shepard					Dated	Jan 12, 2001
Residence:	SOUTHFIELD	State	MI	Country	USA	Citizenship	US
Post Office Address	23656 Hunter's Lane						
City	Southfield	State	MI	Zip	48034	Country	USA

☐ Additional inventors are being named on the ___ supplemental additional inventor(s) sheet(s) PTO/SB/02A attached hereto.

Name of Inventor ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])	Family Name or Surname

Inventor's Signature						Dated	
Residence: City		State		Country		Citizenship	
Post Office Address							
City		State		Zip		Country	